Construction of a Filament-RF hybrid negative ion source at NIFS NBI test stand

china eu india japan korea russia usa

K. Tsumori[1,2], W. Kraus[5], K. Ikeda[1], H. Nakano[1,3], Y. Takeiri[1], K. Saito[1], E. Rattanawongnara[2], K. Nagaoka[1,3], M. Morren[4], P. Veltri[5], S. Briefi[6], B. Heinemann[6], U. Fantz[6], and M. Osakabe[1,2]

[1]National Institute for Fusion Science, [2]The Graduate University for Advanced Studies, [3]Nagoya University, [4]ITER Organization, [5] Technische Universiteit Eindhoven, [6]Max-Planck-Institut für Plasmaphysik

The 9th International Symposium on Negative Ions, Souces and Beams (NIBS'22)
at Padova and online, on 3 – 7 October 2022

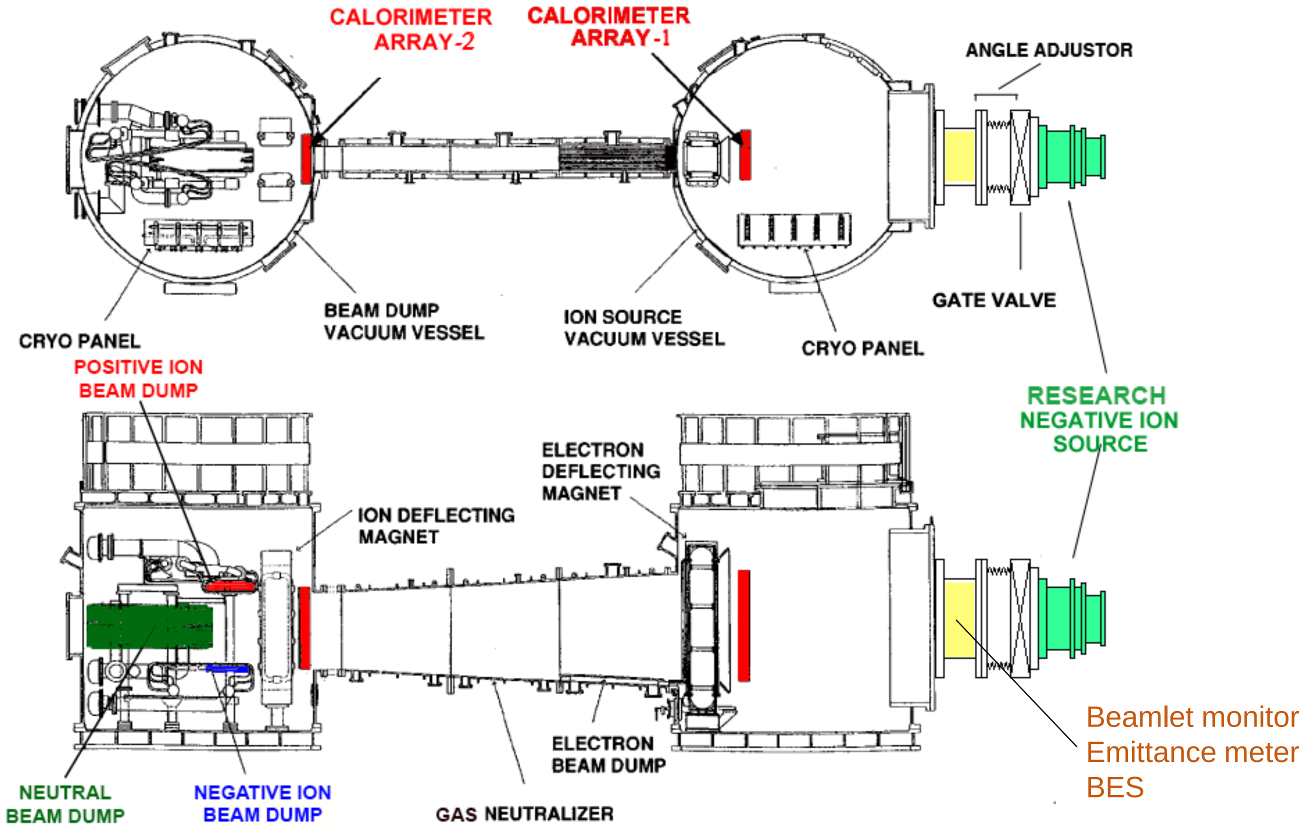
Background

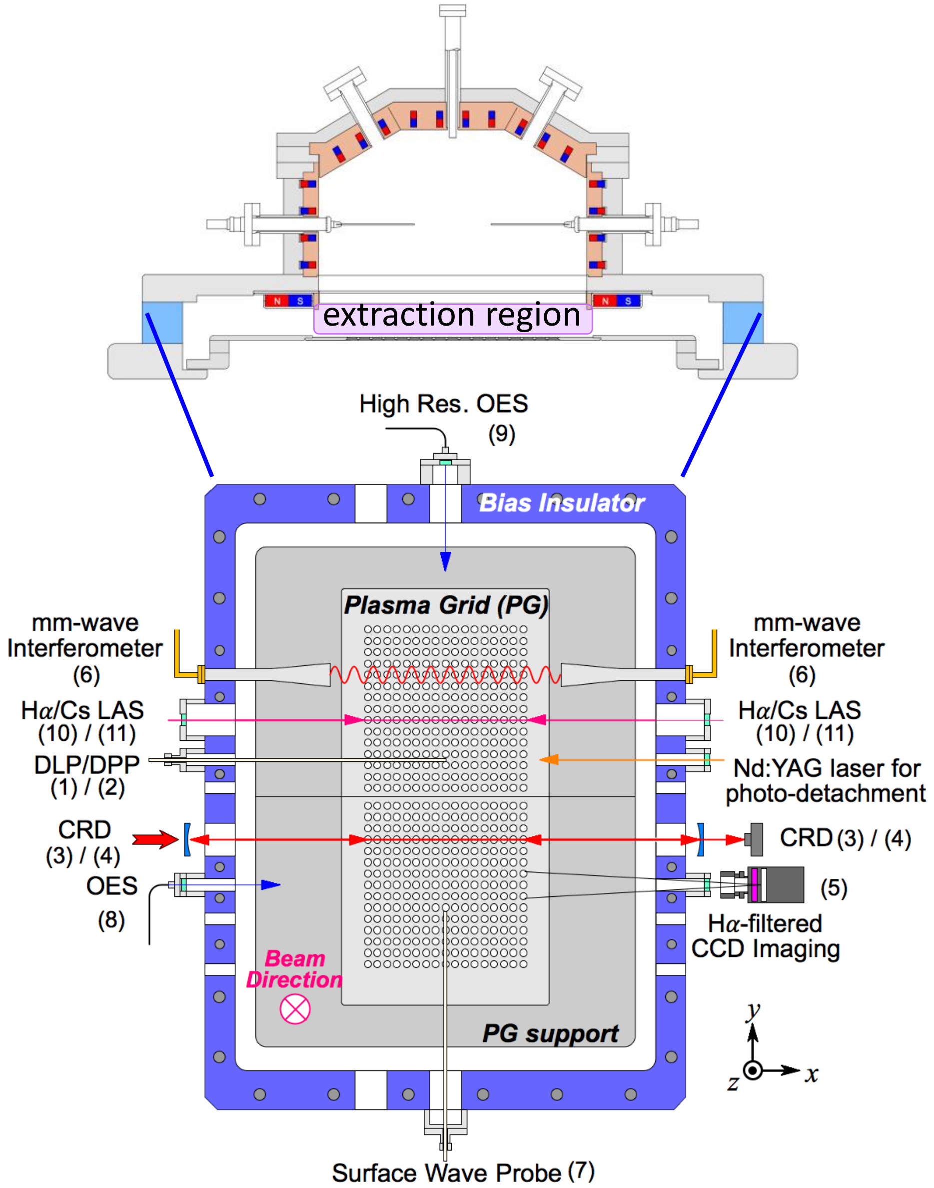
- Reduction of beamlet divergence in RF negative ion source for NBI is one of high-priority targets to be solved.

  Minimum beamlet 1/e divergence

  - min. θ_{div}(FA) ≤ 5 mrad (obtained by NIFS and QST)
  - min. θ_{div}(RF) ≤ 12 mrad (obtained by IPP and RFX)
  - max. θ_{div}(ITER NB) < 7 mrad [P. Vertri *et*. *al*., to be presented later in this conf.].
- To investigate the difference of the beamlet divergence between RF and Filament-Arc (FA) negative ion sources, NIFS NBI gourp contracted a commisioning research on beamlet divergence with the ITER Organization.
- The NIFS NB Test Stand (NBTS) are installed several diagnostic devices to measure the source plasma and beamlet.
- By modifying the NIFS Research Nagative Ion Source (RNIS)
- We report here the progress in the construction of the FA-RF hybrid negative ion source at NIFS NBTS.

NIFS NBTS and It’s Diagnostic System





The NIFS NBTS is equipped an integrated diagnostic system available to measure several physics values of the source plasma and beam at the same time with and w/o beam acceleration.

Features of FA-RF Hybrid Negative Ion Source

- Switchable configuration of FA and RF driven modes.
- Comparison of beamlet divergences in FA and RF discharge modes.
- Dependence of by changing the input power ratio of RF to FA.
- Availablity of the beamlet diagnostic devices such as CFC beamlet monotor, emittance meter and BES.
- Combination of the beamlet measurements above and the measurements of the source plasma by changing the input power ratio.

- Analysis of the relation between beam and source plasma parameters.

- Solution to reduce the beamlet divergence.

List of the items

① Installation of AC 400 V power line for the RF oscillator.

② Additional sub-control system to drive the RF power system.

③ Modification of gas feeding system.

④ Design and construction of the RF backplate.

⑤ Installation of the RF power system from the RF oscillator to the RNIS.

⑥ Modification of the FA control system to match the RF system.

⑦ Additional interlock system for RF system.

List of the items

① Installation of AC 400 V power line for the RF oscillator.

② **Additional sub-control system to drive the RF power system.**

③ **Modification of gas feeding system**.

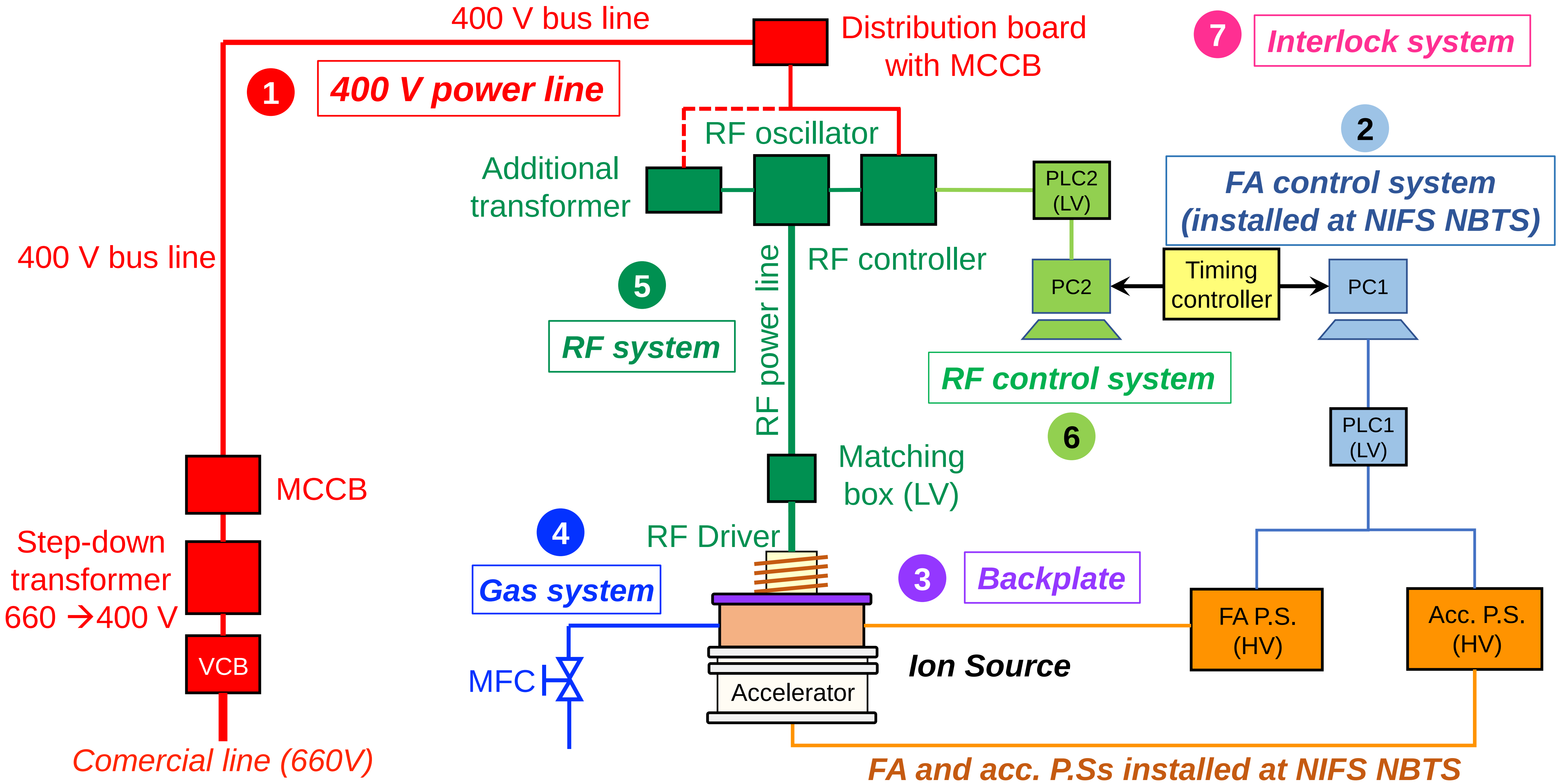
④ **Design and construction of the RF backplate**.

⑤ **Installation of the RF power system from the RF oscillator to the RNIS**.

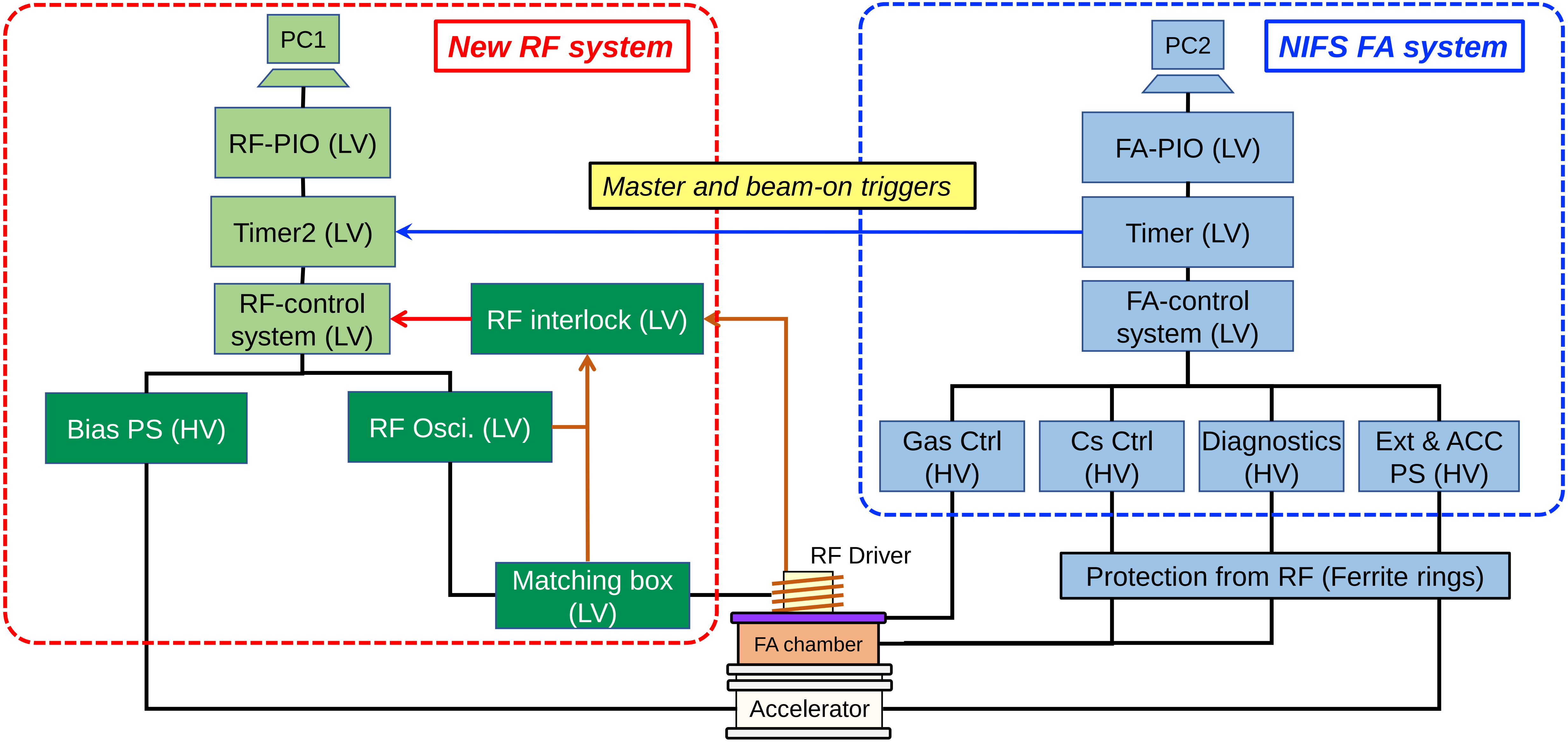
⑥ Modification of the FA control system to match the RF system.

⑦ Additional interlock system for RF system.

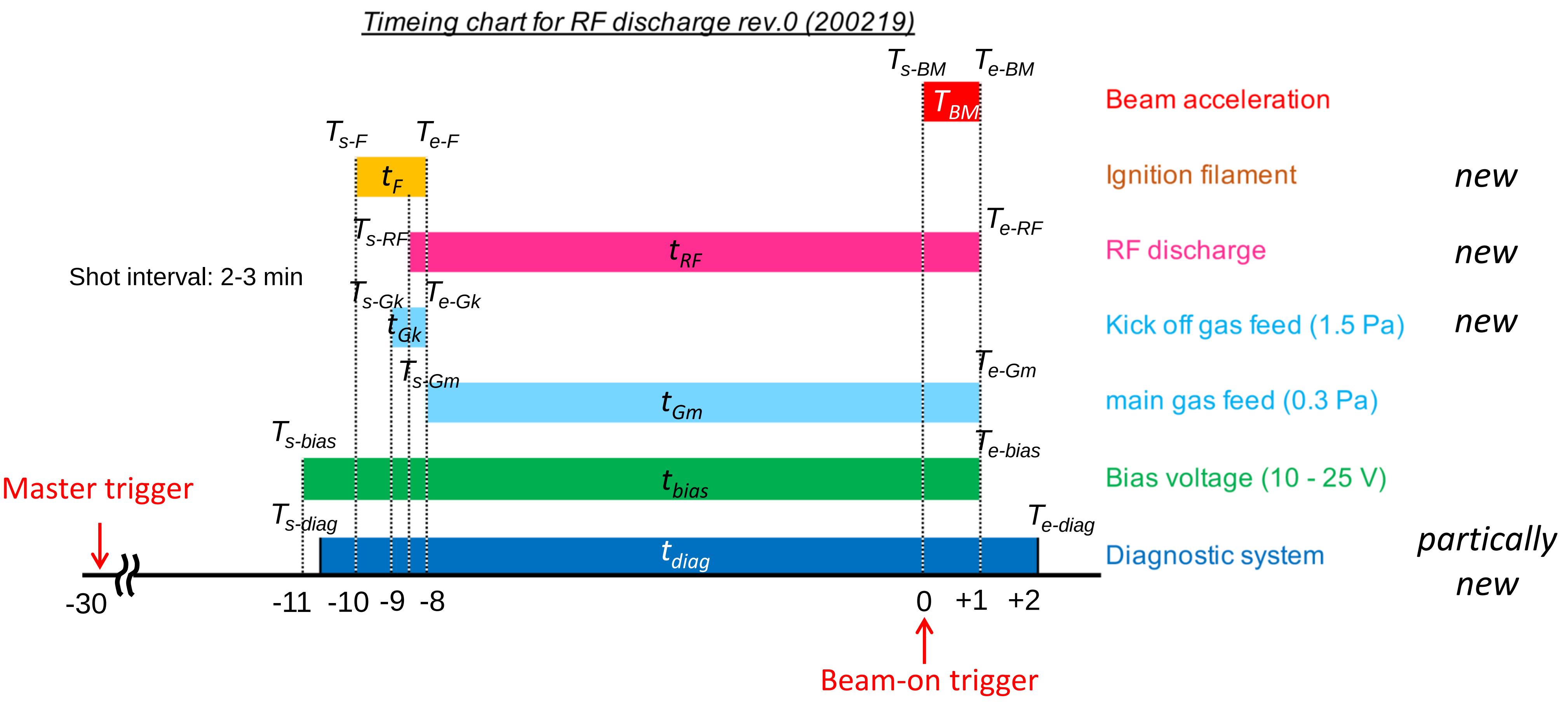
Schematic of the FA-RF system



Linkage of the FA and RF control systems



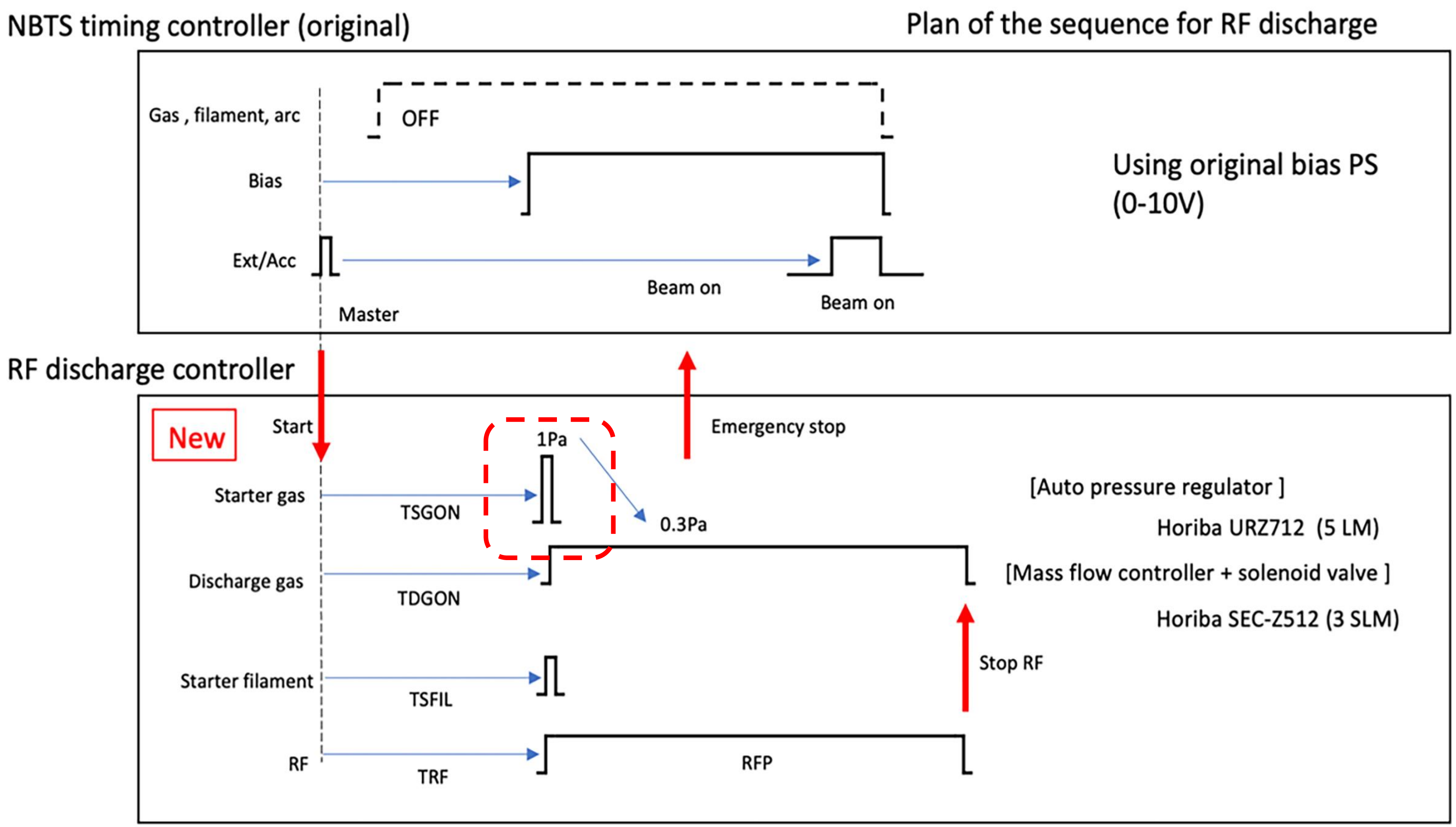
Timing Chart



T_0: timing of master trigger
(master trigger is common with FA controller)

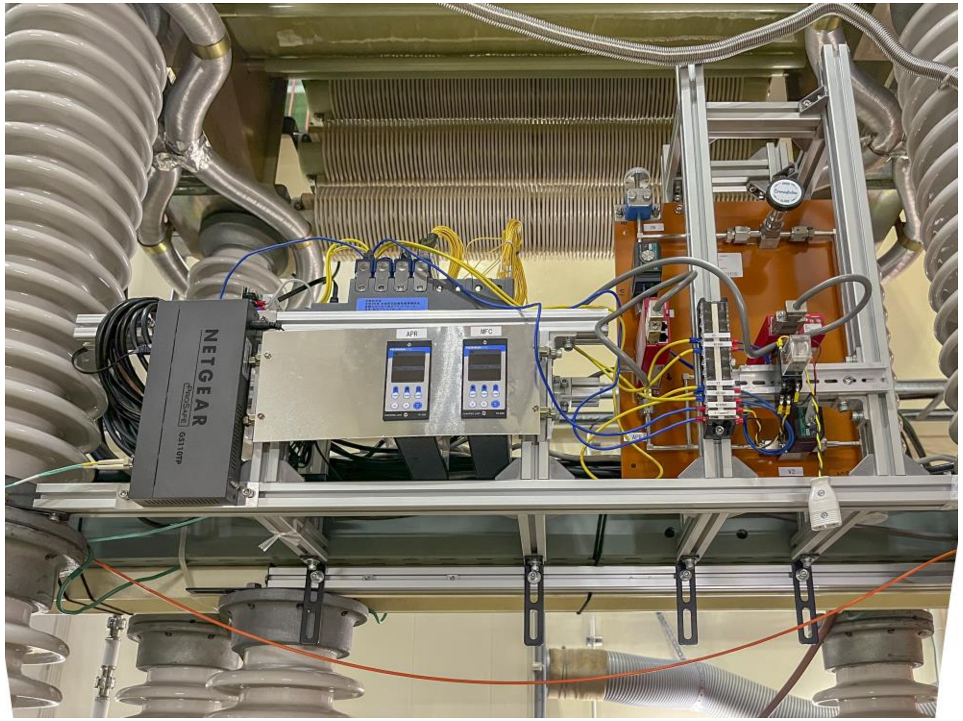
$T_{e\text{-}RF}=T_{e\text{-}Gm}=T_{e\text{-}bias}=T_{e\text{-}bm}$

Timing chart of gas feeding

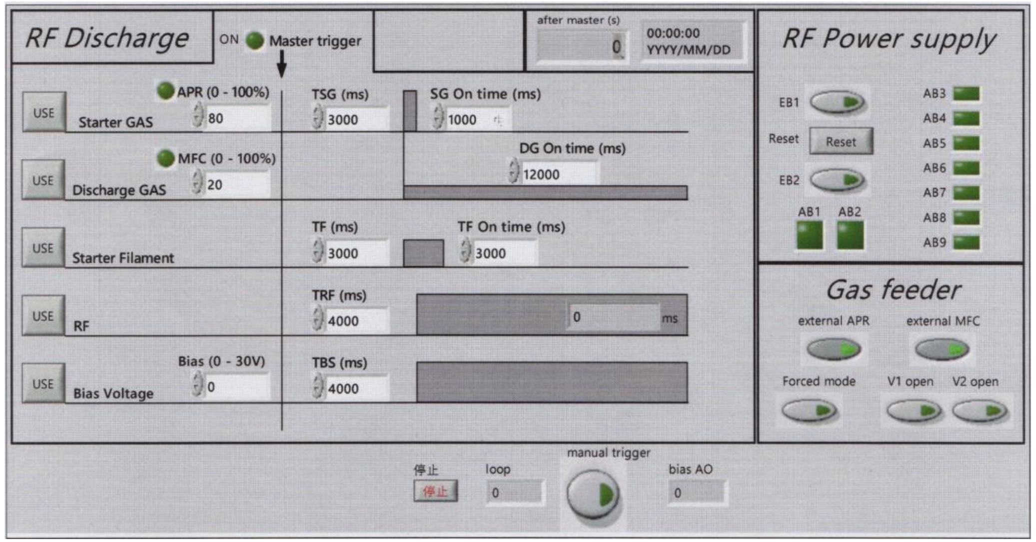


- Previous gas system has one Mass Flow Controller (MFC), while it may necessary to feed kick-off gas to ignite RF plasma.
- For the reason above, two MFC system was designed and installed at the NBTS.
- The new gas sytem will be tuned in the week starting from 3 or 10 October 2022.

Gas Control Module

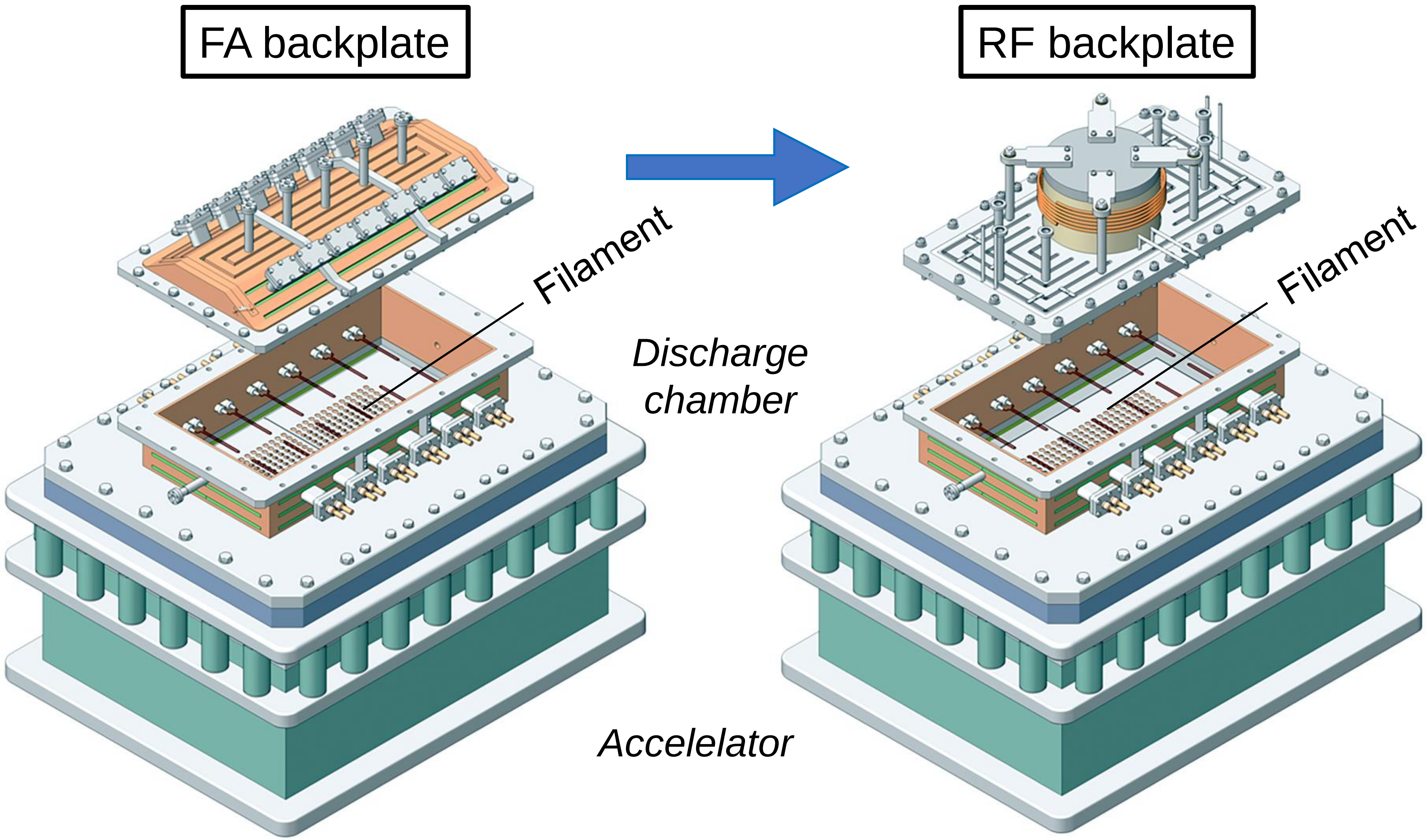


Gas feeding system for RF discharge.
Distance from RF driver is ~1.5 m



LabView interface for RF discharge cotrol including the gas feeding control.

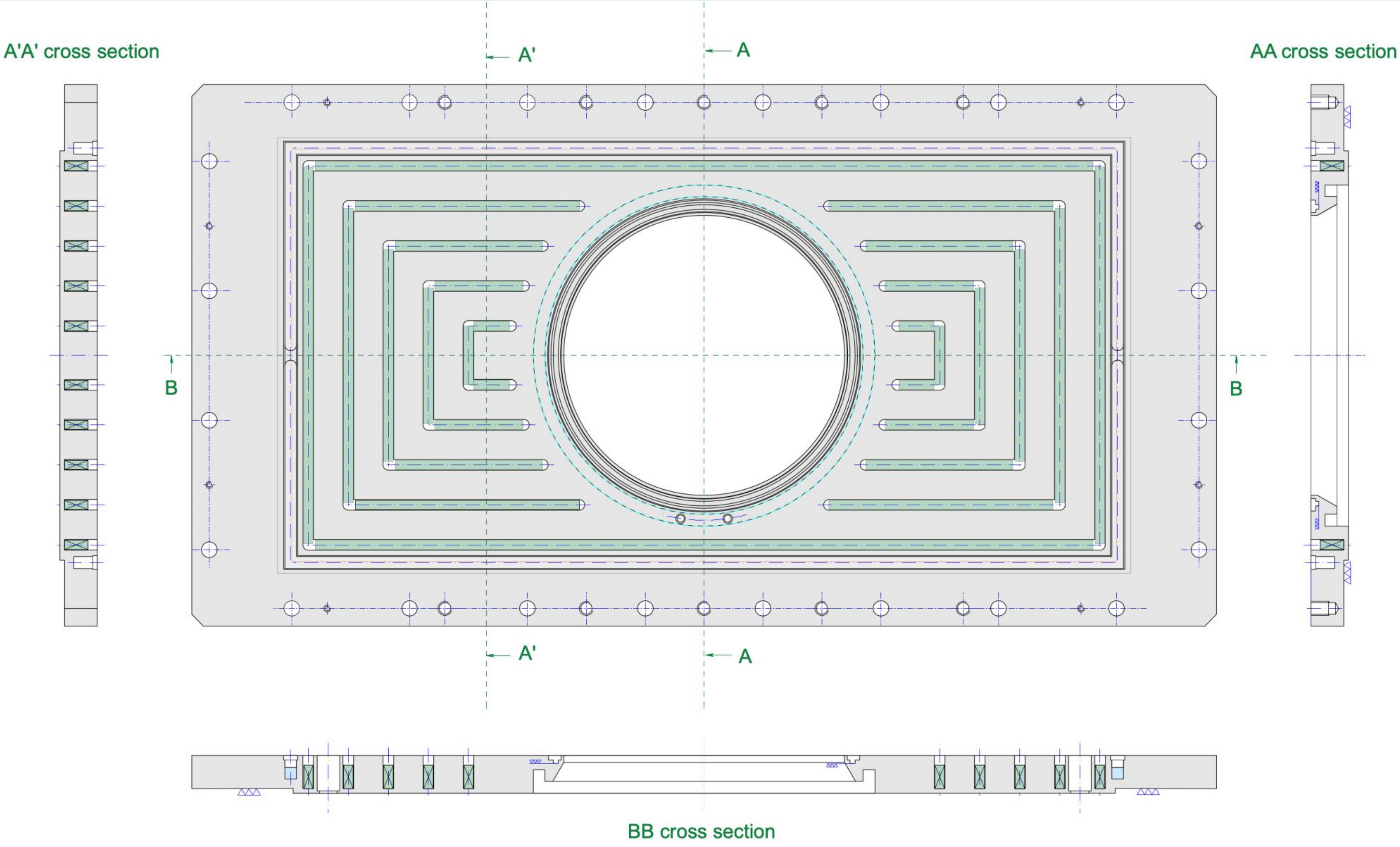
RF backplate



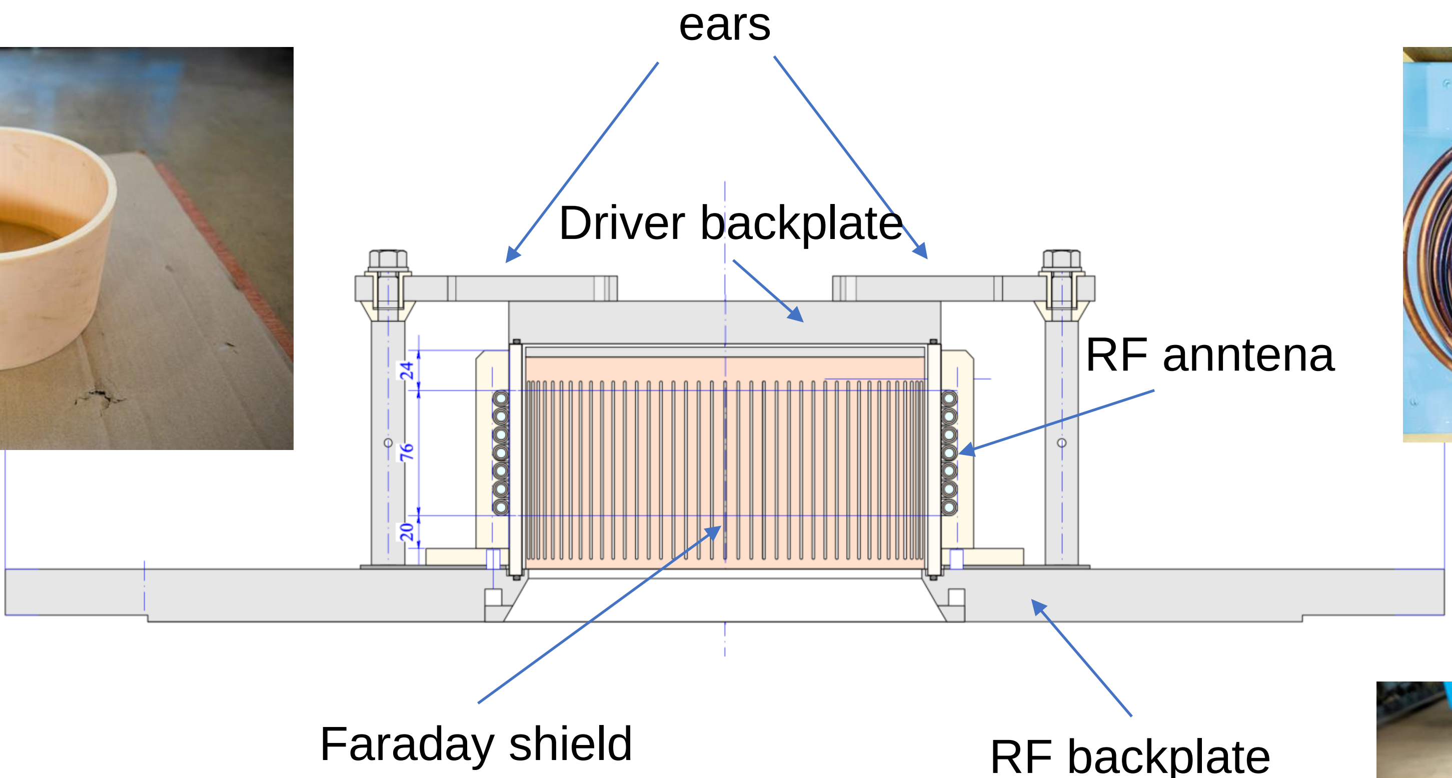
Research Negaive Ion Source (RNIS) installed at NIFS NB Test Stand

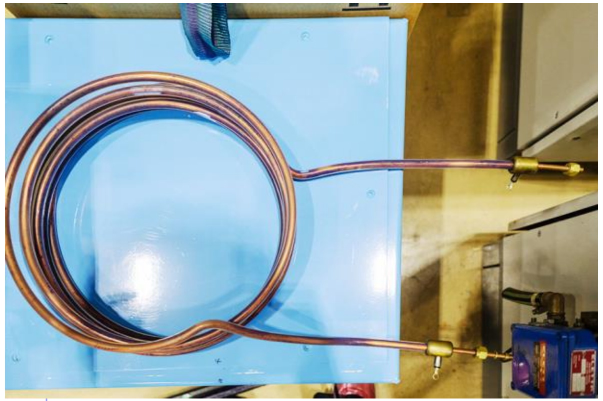
- The fastest way to add RF discharge mode to the Research Negative Ion Source (RNIS) is to replace the backplate with a RF driver.
- The RF backplate has cusp-magnet array similar to FA one for
- This replacement makes available to compare

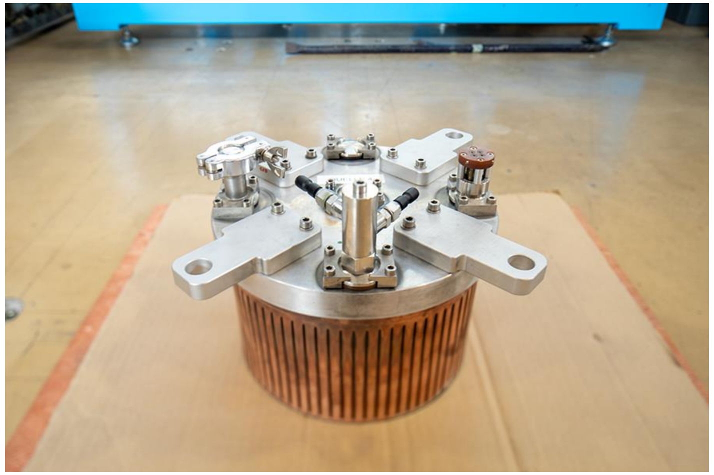
Cusp Magnets in the RF Backplate



RF Driver and RF Backplate

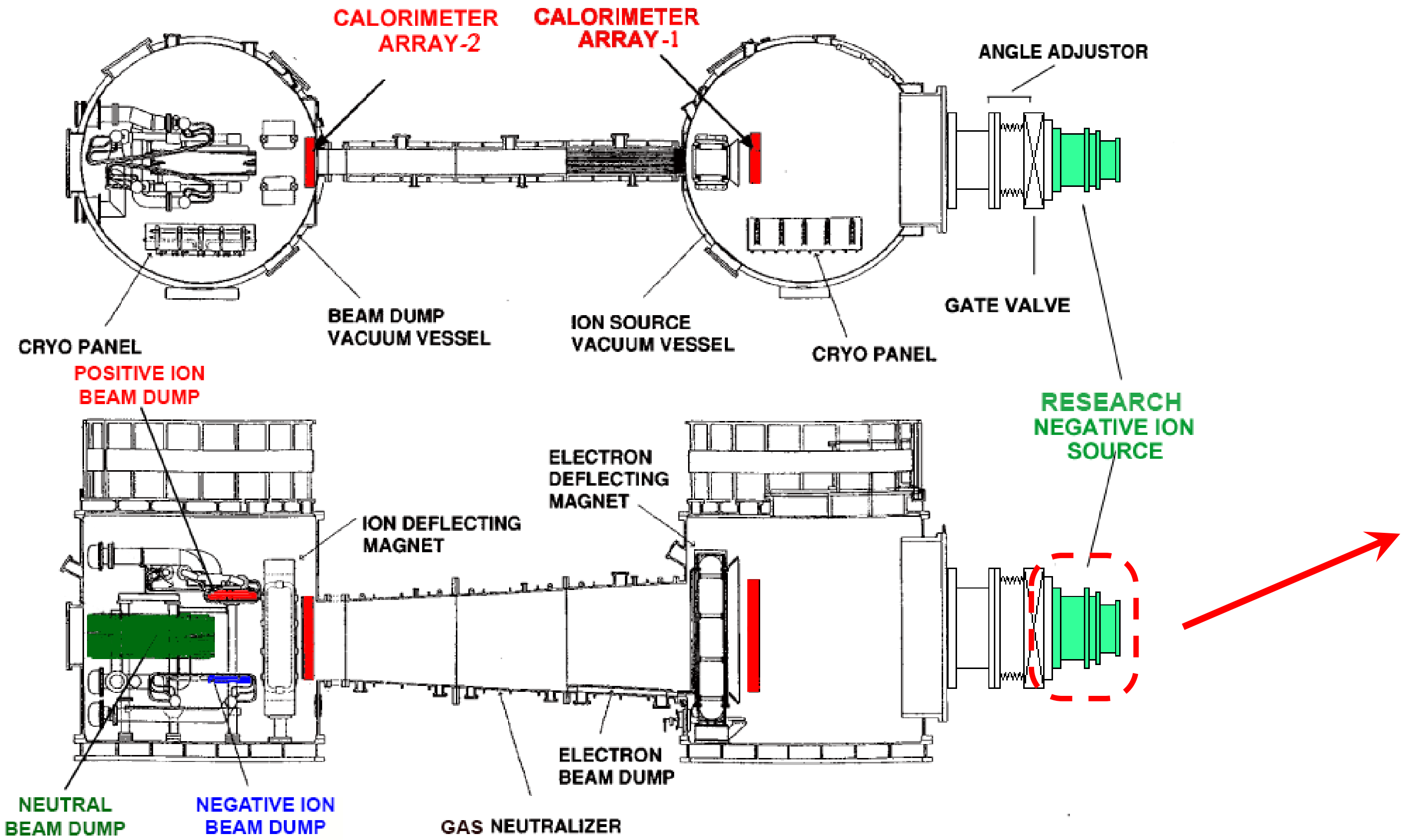


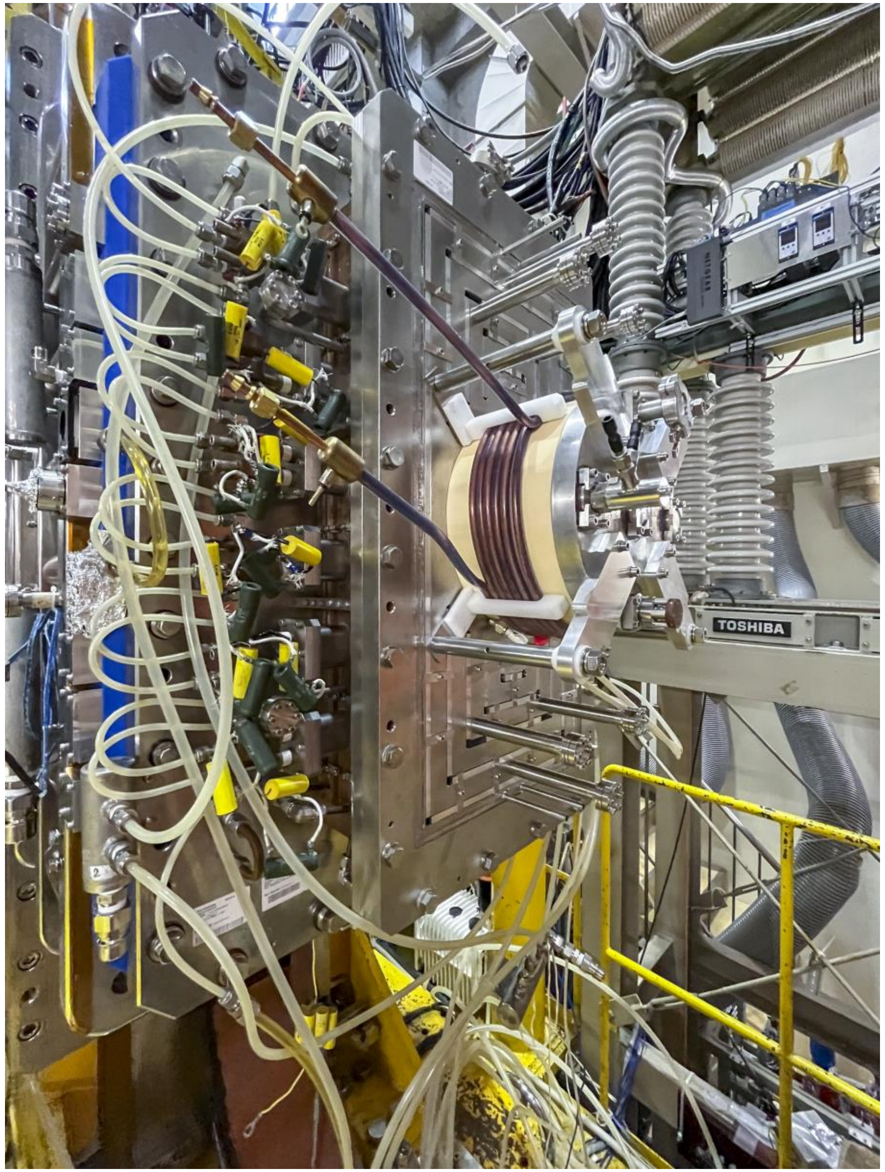




Cross-sectional view of RF driver

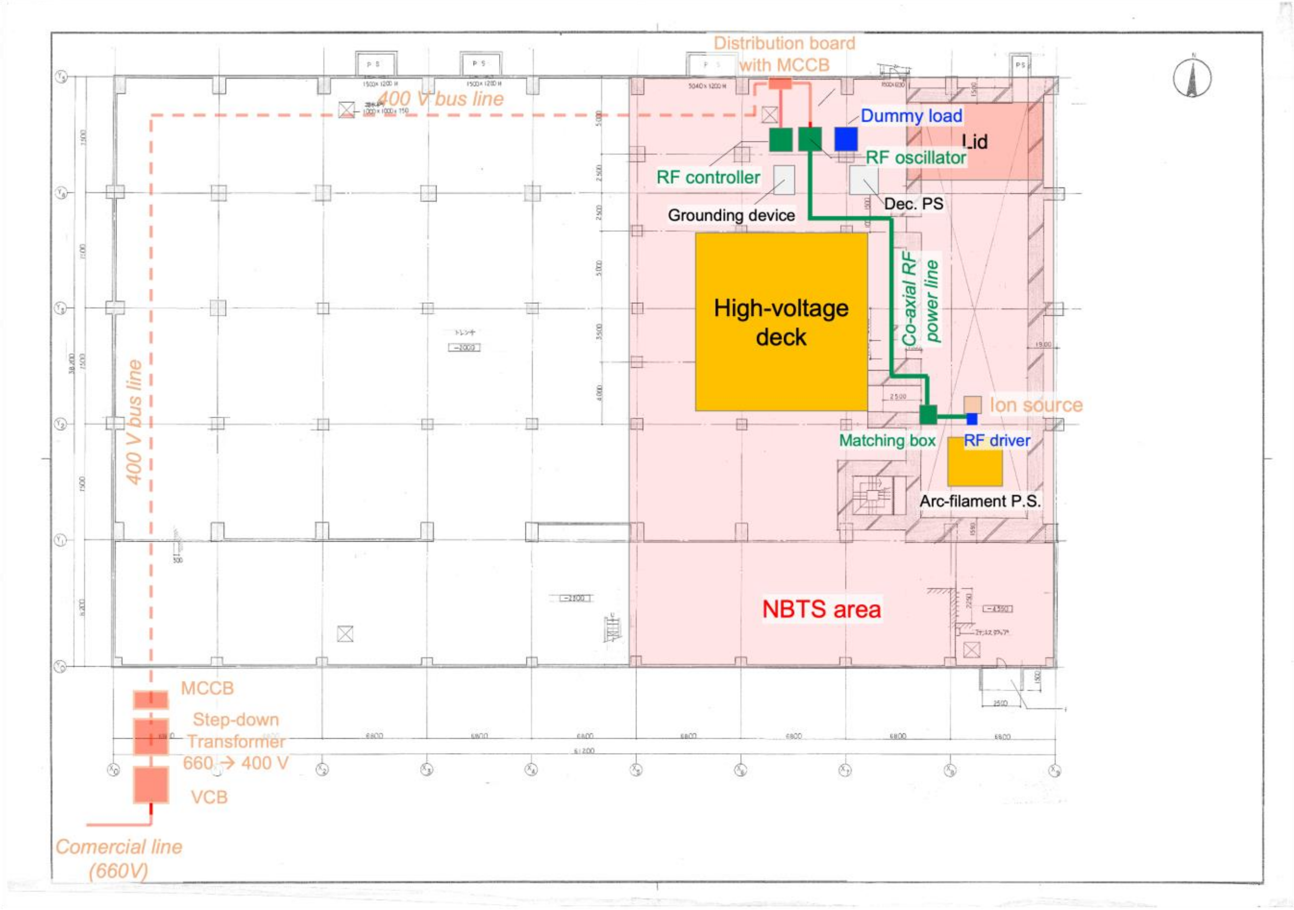
RNIS with RF Driver is installed at NBTS Beamline

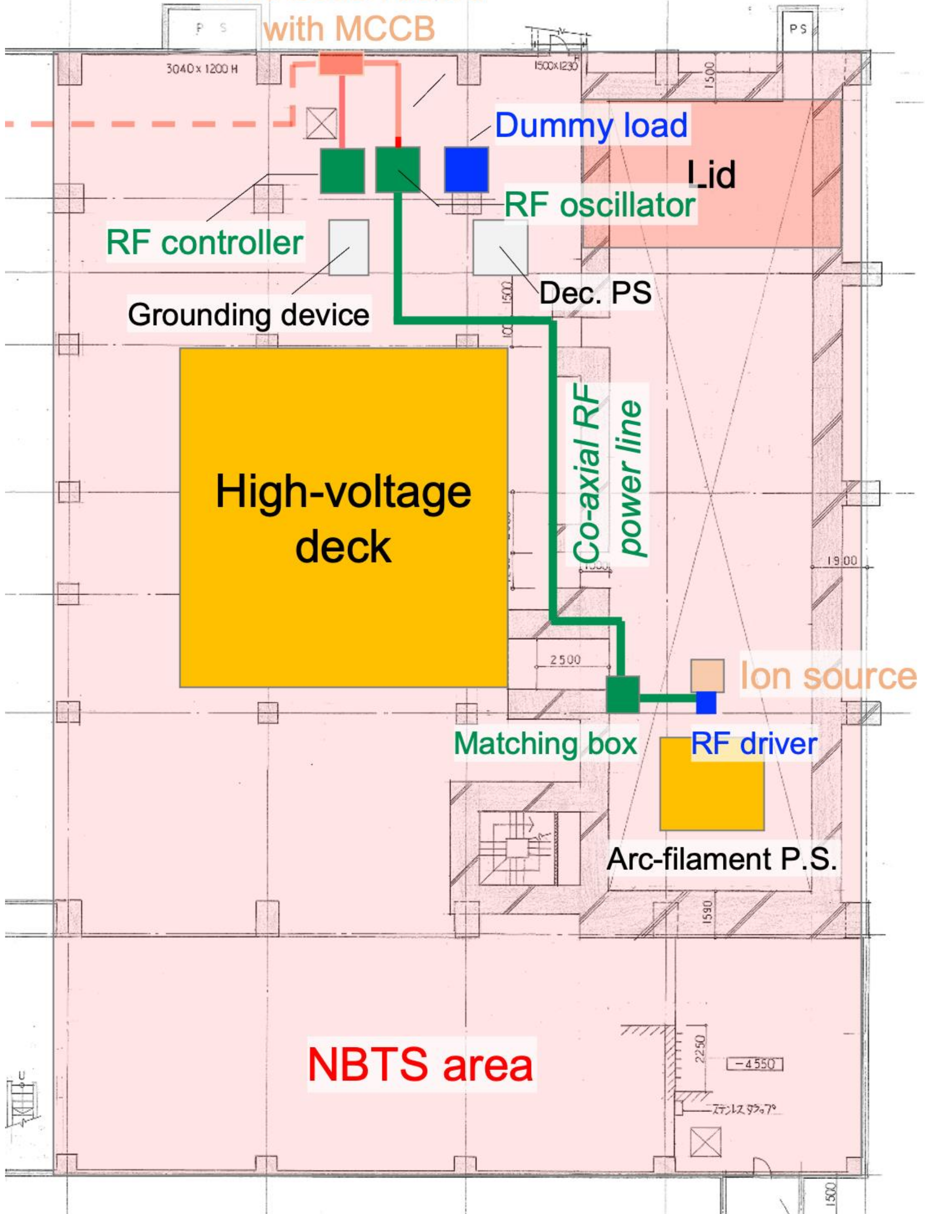




Air leakage at the driver backplate has been fixed at 3 October 2022!

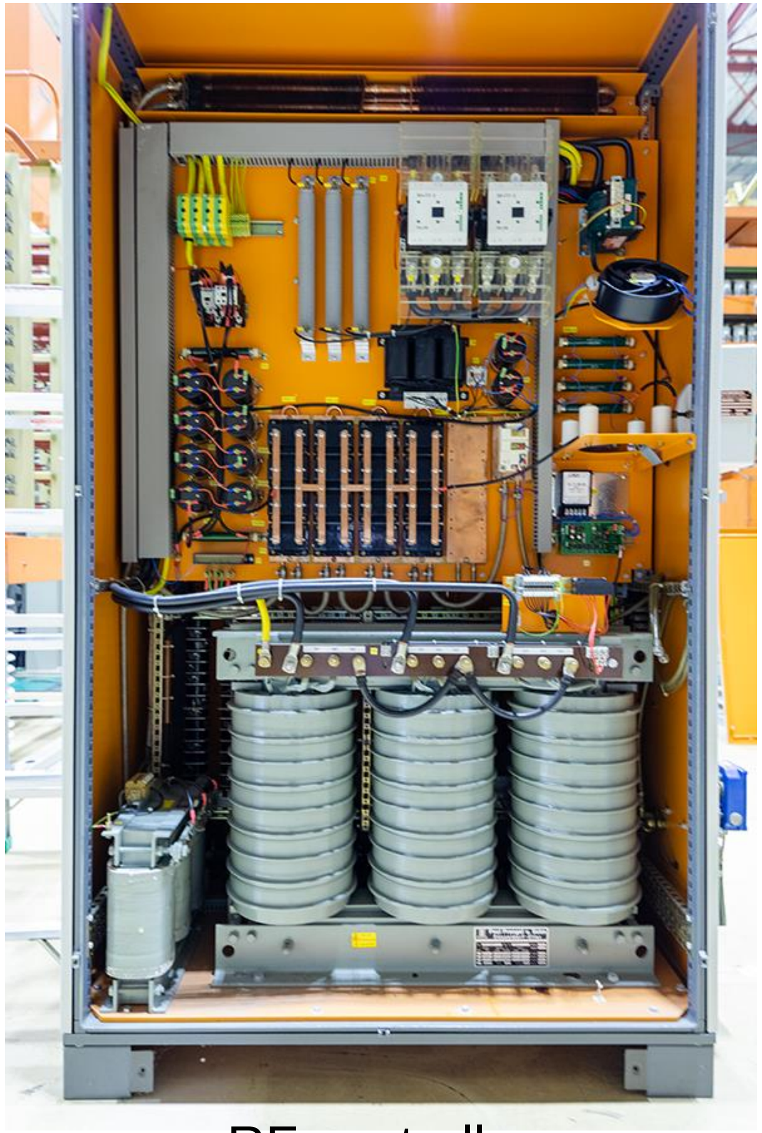
RF Oscillator and the power line



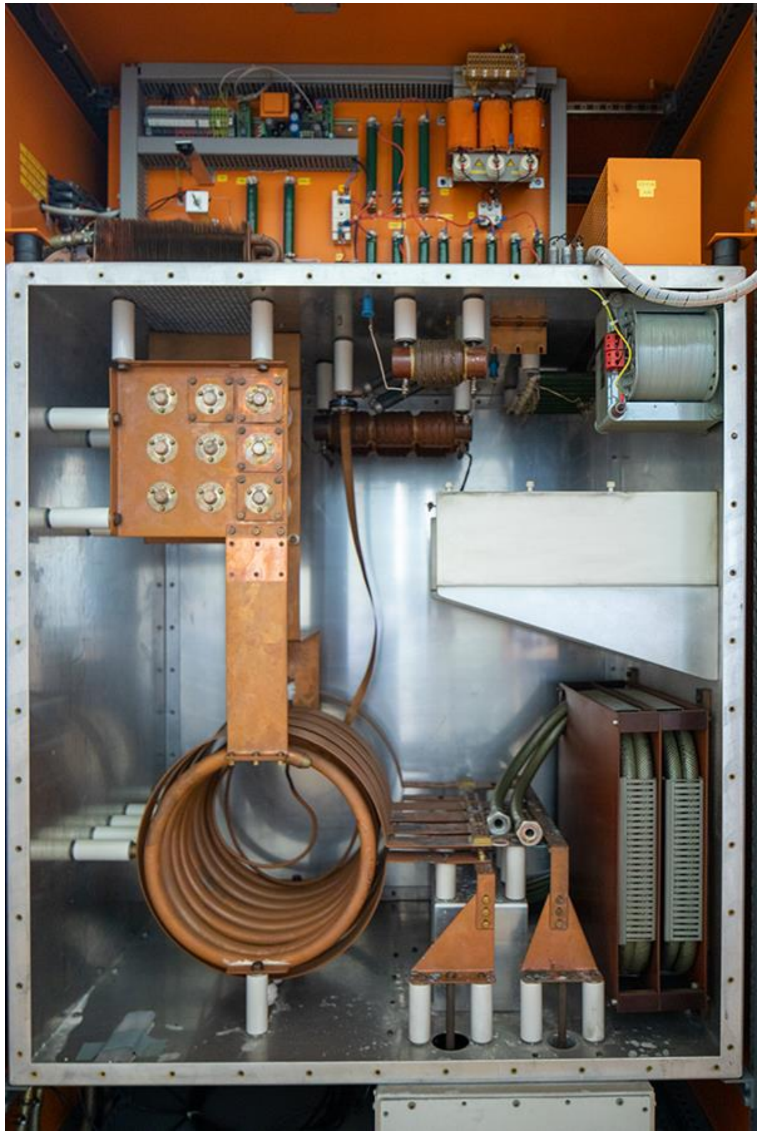


RF power system includes (1) RF controllor, (2) RF oscillator, (3) ext. RF cont. module, (4) RF cable (5) maching box.

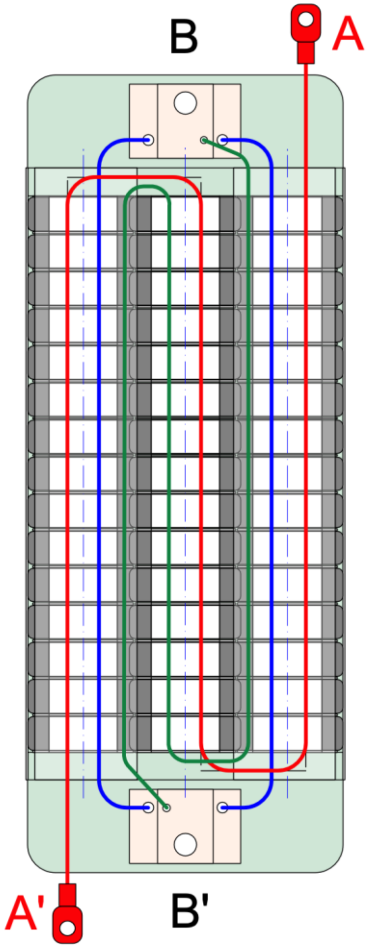
RF Controller, Oscillator and RF insulation Transformer



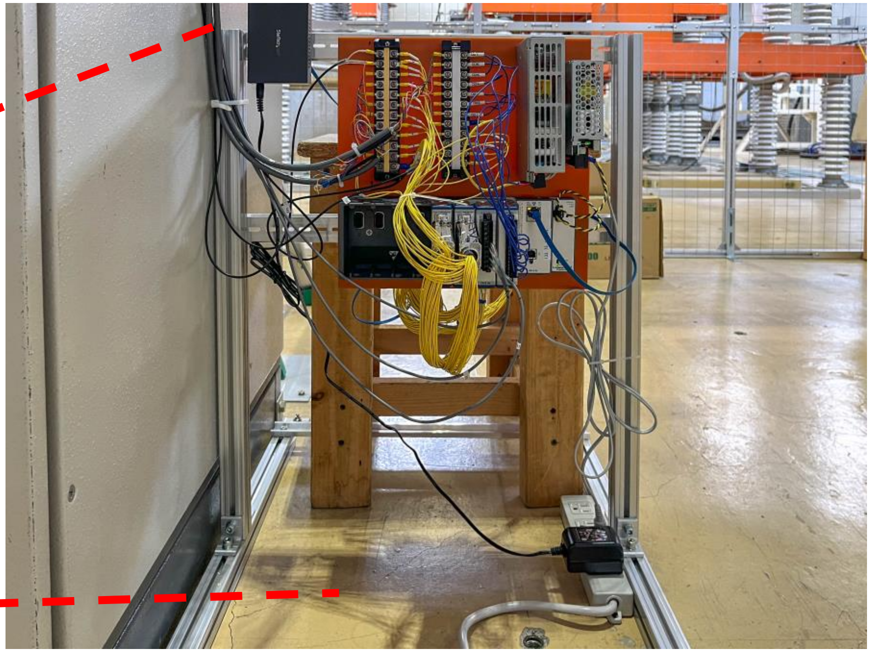
RF controller

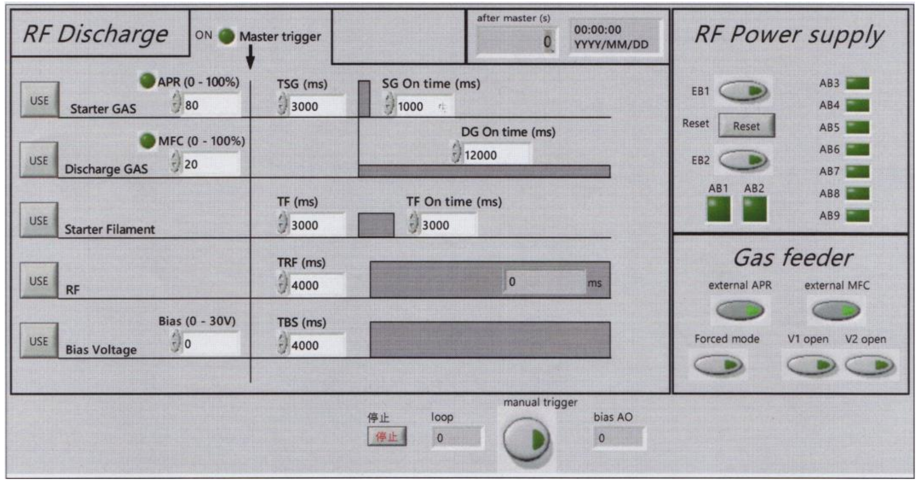


RF oscillator



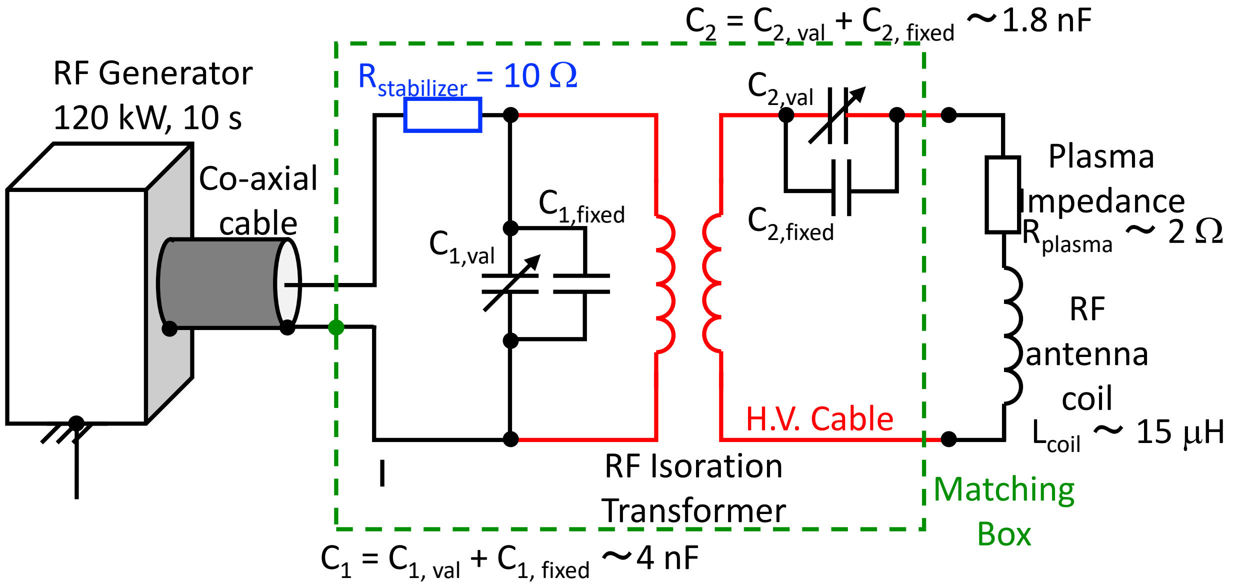
External Control Module





- RF control system is set beside the RF control panel, and control com-mands are sent via ether net.
- At NBTS control room, LabView program in another PC transfers the commands to gas feeding and RF control panel.

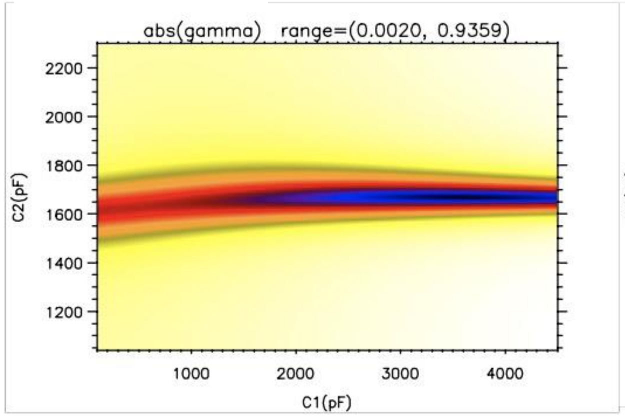
Matching Box



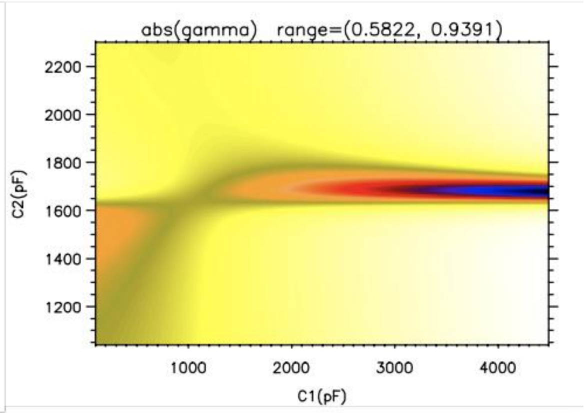
- Matching box is almost ready to build and is moved near the RNIS with RF driver.
- Dry test of the matching box is performed with simulation and network analyser .
- As the next step, the box is going to be tested by connecting the RF oscillator.

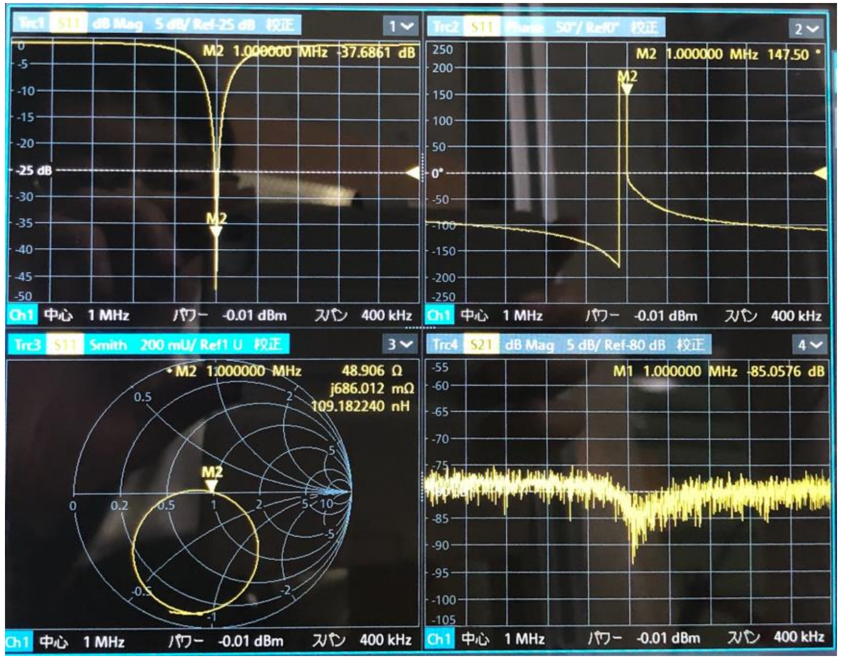
at 2Ω resistance

C1=3600pF
C2=1670pF
Reflectivity =-47.985827dB

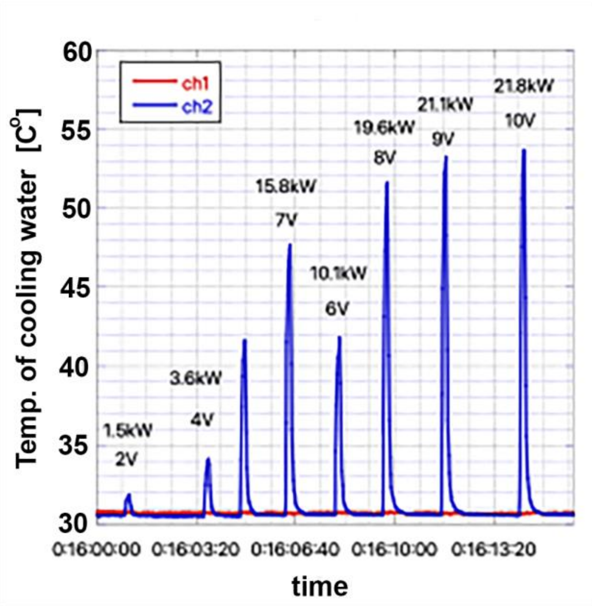


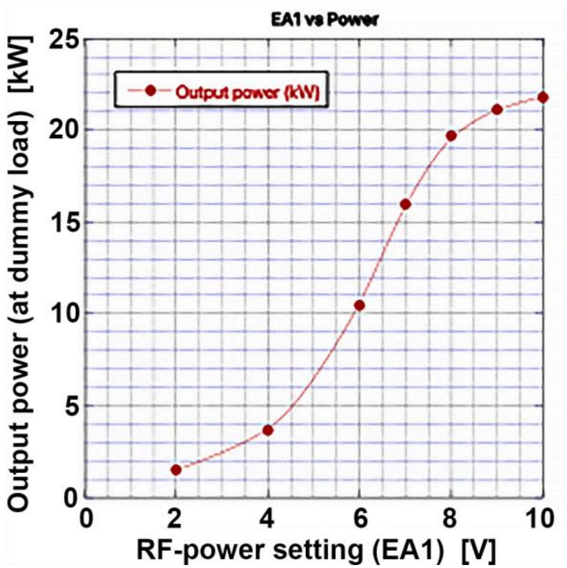
C1=3600pF
C2=1670pF
Reflectivity =-3.2715853dB

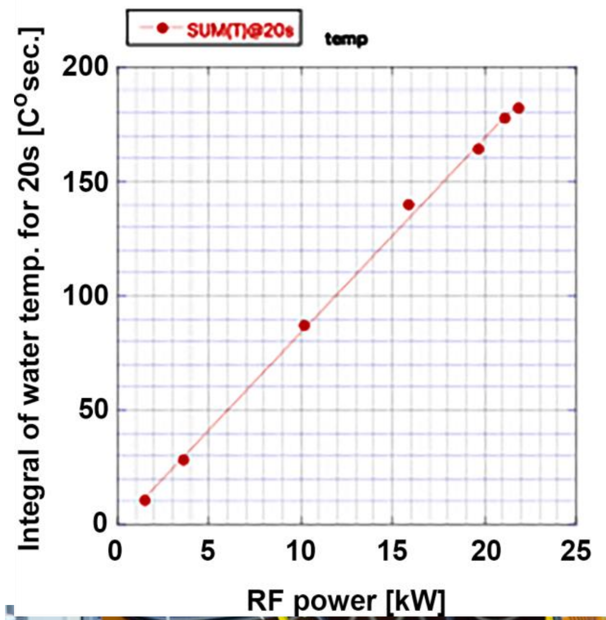


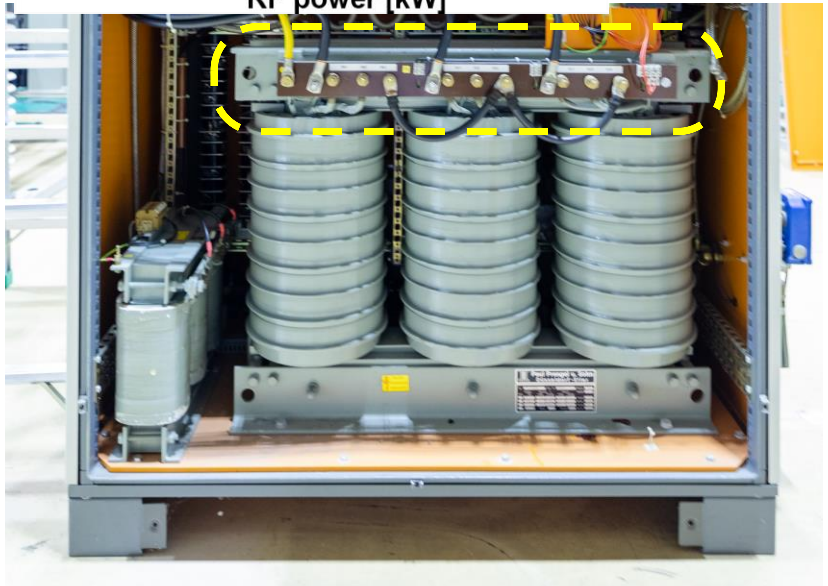


RF Output from Oscillator-1



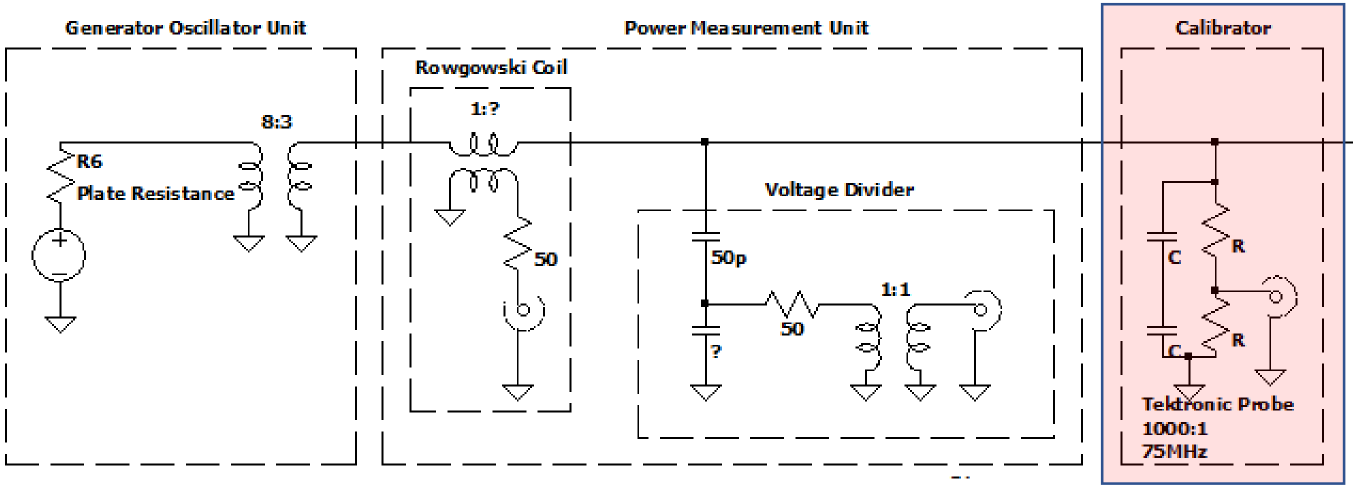


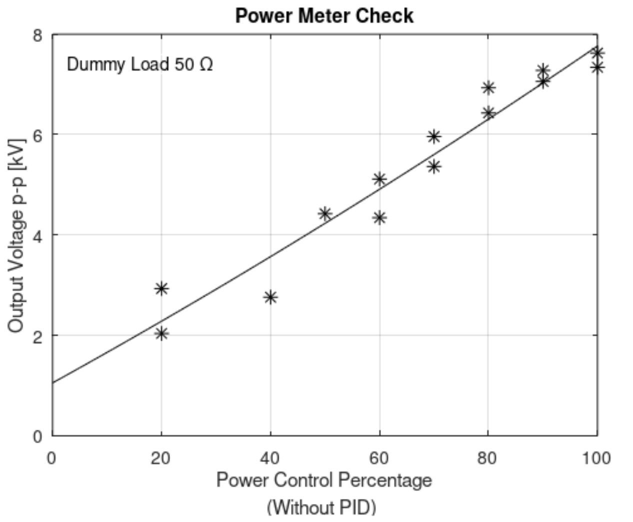


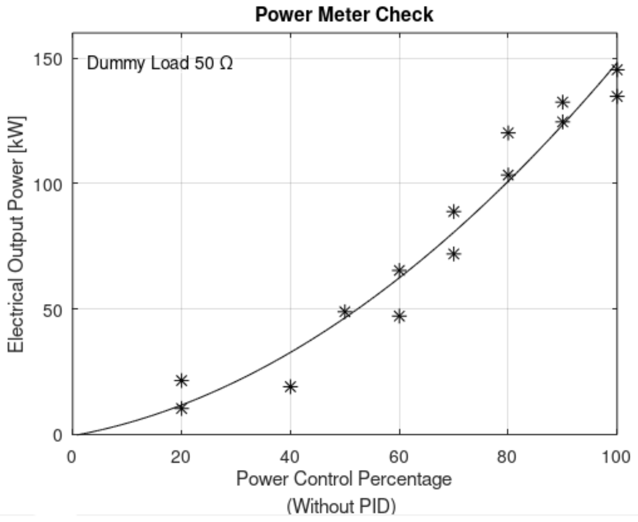


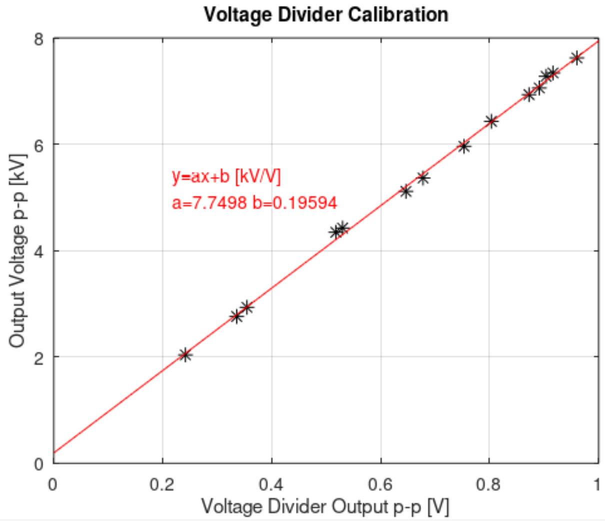
- RF output power increases at the setting value of 60 % (6 V) and starts to saturate.
- The linearity of RF power is propotional to the integral of dummy load water temperature.
- Problem: the maximum RF output power is ~22 kW.
- Later it became clear that the problem is due to the misconnection of the transformer taps at the RF oscillator.
- The RF output increased by 100 % after the reconection.

RF Output from Oscillator-3









Summary

- To investigate the difference of beamlet divergence, FA-RF hybrid system is under construction at NIFS NBTS.
- The difference will be investigated using the data obtained the integrated diagnostic system at the NBTS.
- So far, the hybrid system, especially RF part is intensively constructed.

Acknowlagement

- We would like to appreciate Dr. P. Veltri for his support to this project and also the NBI team od IPP Garching for their effort to export the RF oscillator and several materials from Germany and support the experiment.
- We would like to thank to Dr. W. Kraus, who is an invited scientest at NIFS, for his significent supports to construction of the FA-RF hybrid system.

Thank you for your attenton!